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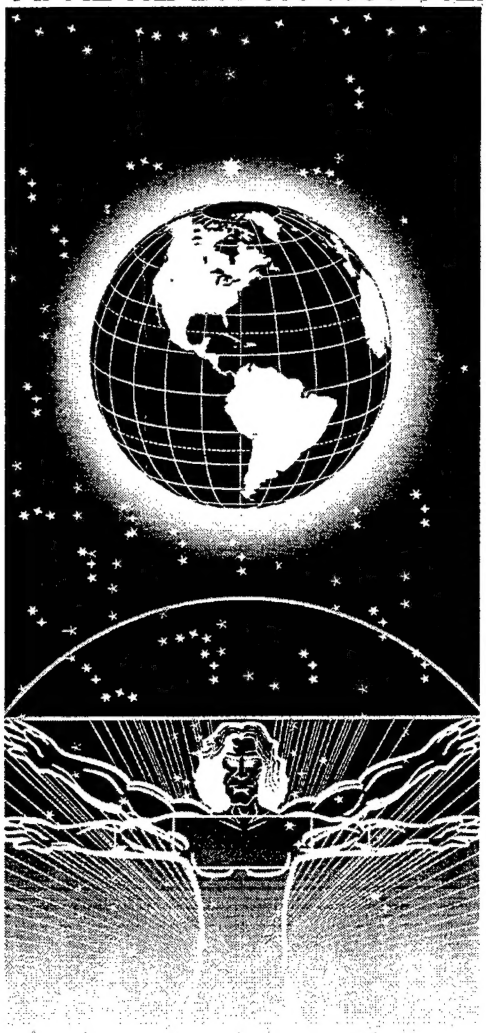

UNITED STATES AIR FORCE
RESEARCH LABORATORY

TESTING AND EVALUATION OF THE UNITRON, INC., MODEL PS-95-448-1, MEDI-VAC PORTABLE POWER SYSTEM

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NOTICES

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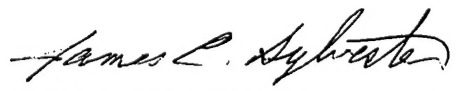

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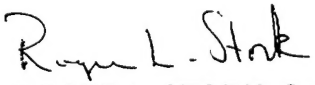

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The Unitron, Inc., Model PS-95-448-1, Medi-Vac Portable Power System is a portable frequency converter that converts 400 Hz, 3-phase, 115/200 VAC aircraft power into 60 Hz, single-phase, 115 VAC power for power distribution used to run medical equipment. The unit operates on 115 VAC/400 Hz power (Figure 1). The unit weighs approximately 51.16 lbs. and is 10.5 in. W. X 12.75 in. H. X 23 in. D.

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ACKNOWLEDGMENTS

I would like to thank those who helped and provided advice during the evaluation of the Unitron, Inc., Model PS-95-448-1, Medi-Vac Portable Power System. I would especially like to thank:

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Mr. Edward Hade:	Electronics Engineer
Mr. Victor Elizondo:	Electronics Technician

TESTING AND EVALUATION OF THE UNITRON, INC., MODEL PS-95-448-1, MEDI-VAC PORTABLE POWER SYSTEM

BACKGROUND

The Unitron, Inc., requested the Air Force Medical Equipment and Development Laboratory's participation in evaluating and approving their model PS-95-448-1, Medi-Vac Portable Power System for use on board USAF aeromedical evacuation aircraft. Specific components of the Model PS-95-448-1, Medi-Vac Portable Power System that under went the evaluation process included the model PS-95-448-1, Medi-Vac Portable Power System (P/N: 80-17001-3). All components of the model PS-95-448-1, Medi-Vac Portable Power System were tested for air worthiness. Throughout this report, the term Equipment Under Test (EUT) refers to the model PS-95-448-1, Medi-Vac Portable Power System.

DESCRIPTION

The EUT is a portable frequency converter that converts 400 Hz, 3-phase, 115/200 VAC aircraft power into 60 Hz, single-phase, 115 VAC power for power distribution used to run medical equipment. The unit operates on 115 VAC/400 Hz power (Figure 1). The unit weighs approximately 51.16 lbs. and is 10.5 in. W. X 12.75 in. H. X 23 in. D.

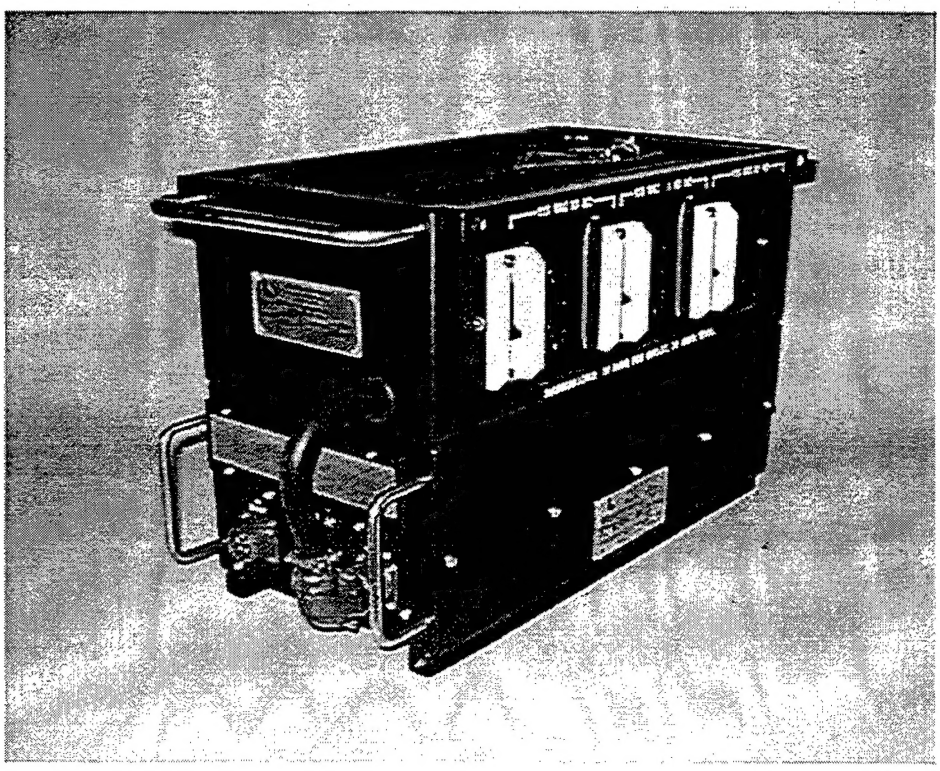


Figure 1. The Unitron, Inc., Model PS-95-448-1, Medi-Vac Portable Power System.

PROCEDURES

Test methods and performance criteria were derived from nationally recognized performance guidelines (1 & 2), military standards (3-8), and manufacturer's literature (9). The Aeromedical Research Procedures Guide describes additional safety and human interface issues to be considered during equipment testing (10). A test setup and performance check was developed specific to this EUT to verify its proper functioning under various testing conditions. All tests are conducted by Air Force Medical Equipment and Development Laboratory (AFMEDL) personnel assigned to the Systems Research Branch, Biodynamics and Protection Division, Human Effectiveness Directorate, Air Force Research Laboratory, Brooks AFB, Texas, unless otherwise noted.

The EUT was subjected to various laboratory and inflight tests to observe and evaluate its performance under anticipated operational conditions.

1. Initial Inspection

2. Vibration

3. Electromagnetic Interference (EMI)

4. Thermal/ Humidity Environmental Conditions, encompassing:

    a. Hot Operation

    b. Cold Operation

    c. Humidity Operation

    d. Hot Temperature Storage

    e. Cold Temperature Storage

5. Hypobaric Conditions

    a. Cabin Pressure/Altitude

    b. Rapid Decompression to Ambient Pressure

6. Airborne Performance

INITIAL INSPECTION AND TEST PREPARATION

a. The EUT was inspected for quality of workmanship, production techniques and pre-existing damage.

b. The EUT was checked to ensure it met safety requirements and operating characteristics established in National Fire Protection Agency (NFPA) 99 (1); AFI 41-203, Electrical Shock Hazards (3); AFI 41-201, Equipment Management in Hospitals (4). Ground resistance and leakage current measurements were made at 115 VAC/60 Hz and 115 VAC/400 Hz.

c. The EUT was examined to ensure it met basic requirements for human factor design as outlined in MIL-STD 1472 (5).

d. A test setup and performance check was developed to evaluate the EUT's operation in accordance with manufacturer/customer specifications throughout the various testing conditions.

TEST SETUP

Placed EUT on a level surface. Plugged the test loads into the power receptacles on EUT. Connected the unit to a 400 Hz power source. Turned unit on.

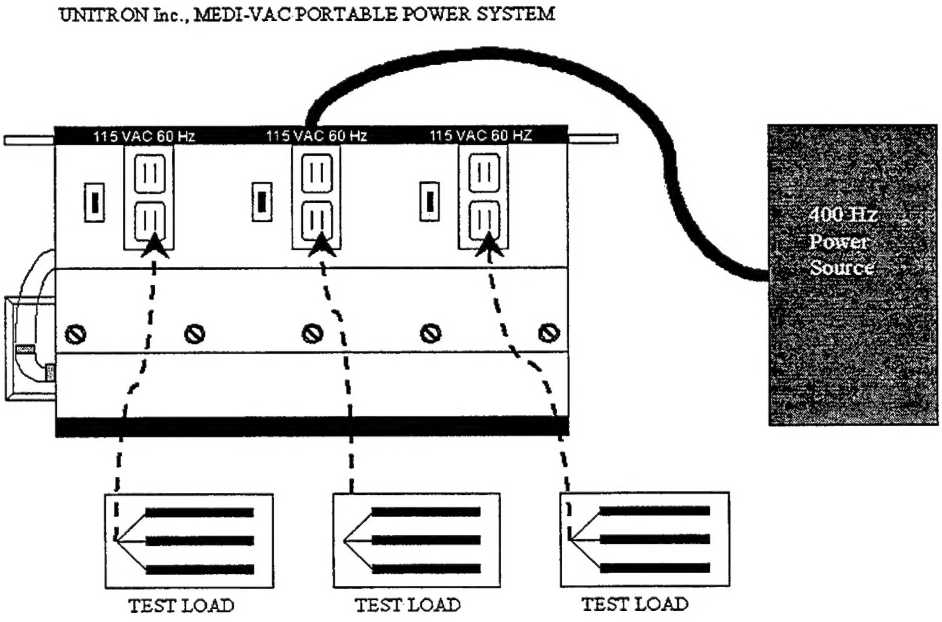


Figure 2. Test Setup

PERFORMANCE CHECK

The following performance check was used to validate the function of the EUT during each of the following test conditions: After unit was configured IAW test set-up procedures oscilloscope leads were attached to view amplitude, frequency and stability of signal. A multimeter was used to measure voltage and current levels.

VIBRATION

Vibration testing is critical to determine "the resistance of equipment to vibrational stresses expected in its shipment and application environments" (6). Testing was conducted on a Unholtz-Dickey Corporation Vibration Test System, amplifier model SA30 and shaker model R16W. This testing involved a set of operational tests performed along each of three axes - X, Y, and Z. The EUT's components were mounted on a NATO litter segment on the vibration table as it would be secured in the aircraft (Figure 3). They were subjected to vibration curves with similar intensities and durations as those derived from MIL-STD-810E, Category 10, Figures 514.4-16 and 514.4-17 (Figure 4).

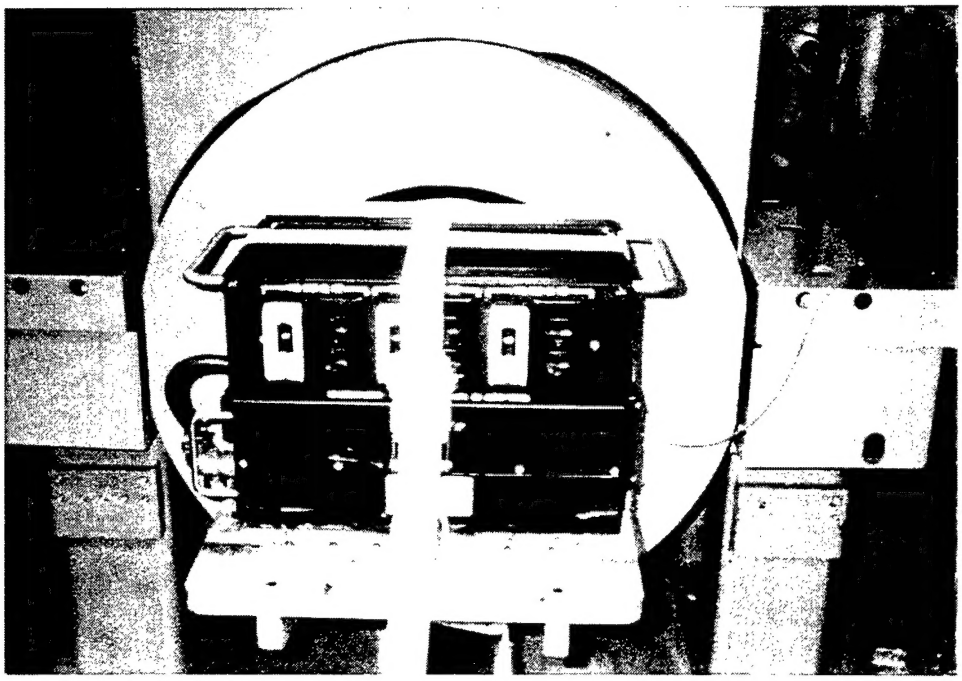
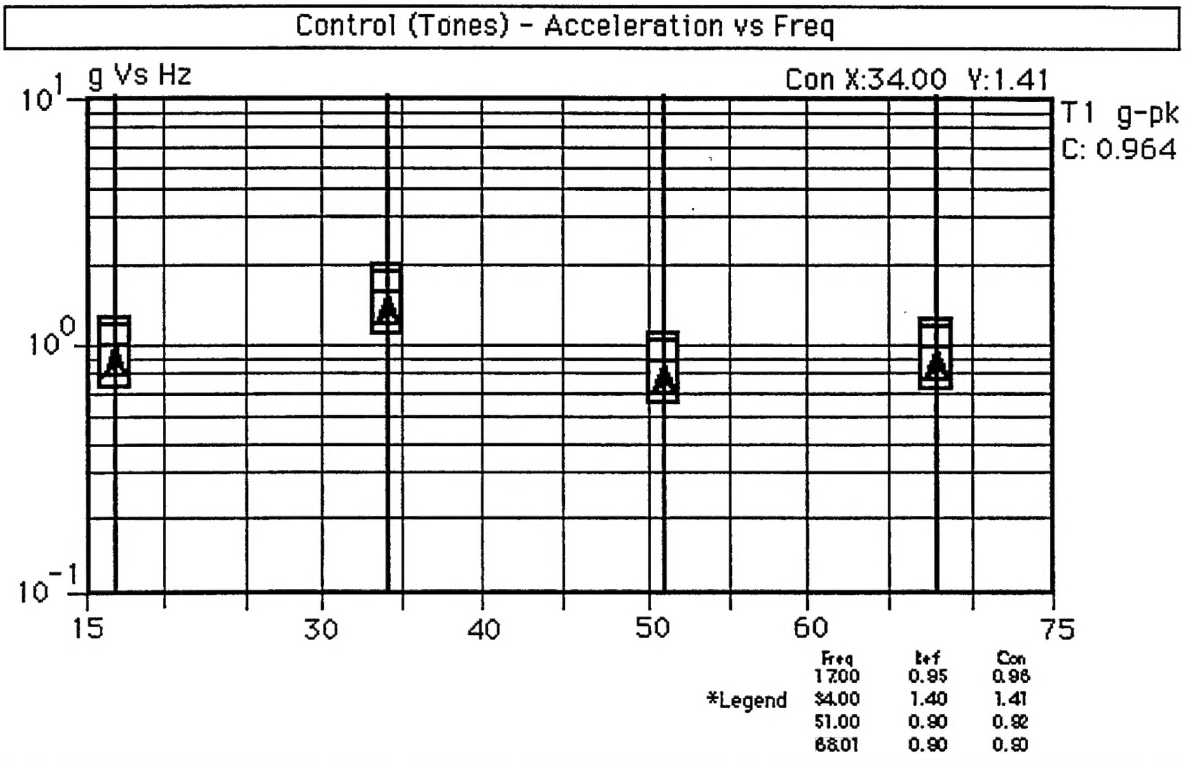


Figure 3. Vibration Table Mounting

Sine-on-Random Curves



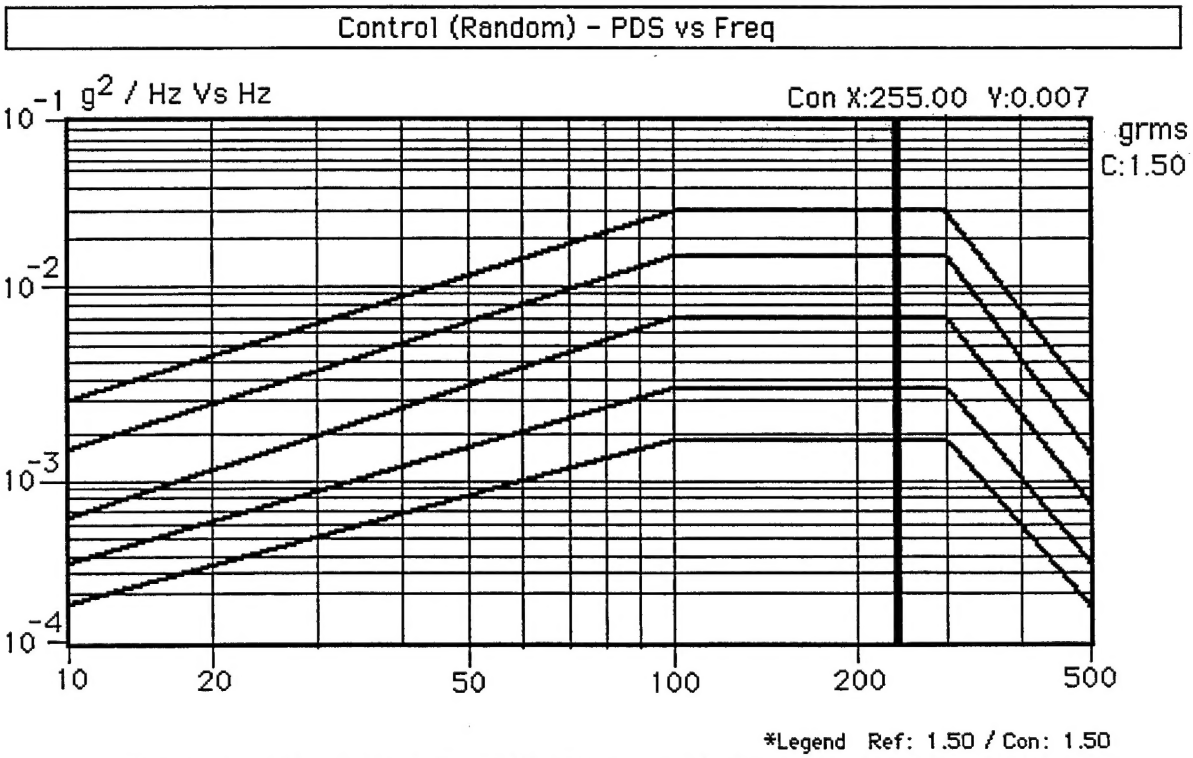


Figure A and B. MIL-STD-810E, Category 10, figures 514.4-16 and 514.4-17

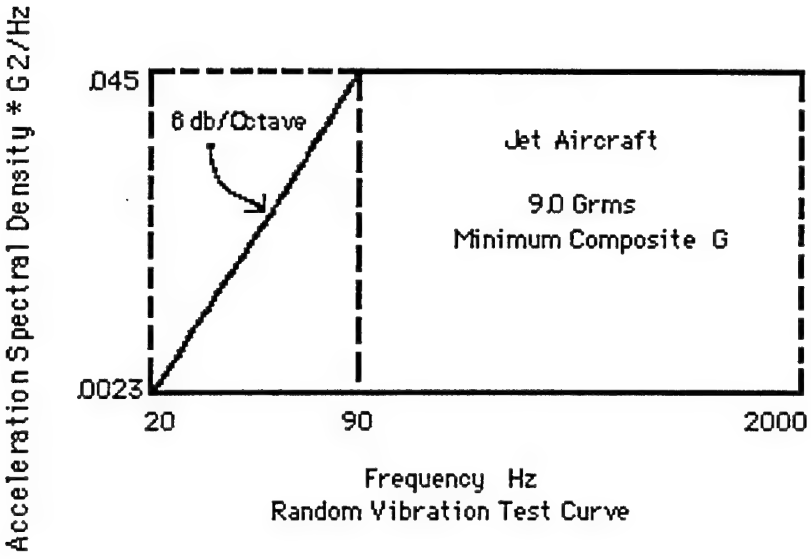


Figure C. MIL-STD-810E, Category 10, figures 514.4-16 and 514.4-17

ELECTROMAGNETIC COMPATIBILITY

Electromagnetic compatibility testing is a primary concern on USAF aeromedical evacuation aircraft. Safety is the driving factor to assessing the effects of excessive electromagnetic emissions and potential influence on aircraft navigation and communications equipment. Medical devices may be susceptible to fields generated by aircraft equipment and malfunction in their presence.

The EUT was evaluated for compliance with MIL-STD-461D & MIL-STD-462D (7 & 8). ASC/ENAI engineers at Wright-Patterson AFB evaluated the electromagnetic compatibility data and determined the airworthiness of the medical device. Specific tests conducted were as follows:

a. Radiated Emissions (RE-102), "Radiated Emissions, Electric Field, 10 kHz to 18 GHz.": For Air Force aircraft applications, radiated emissions were tested in a narrower range of frequencies from 2 MHz - 1 GHz. This test measured the amount of EMI emitted by the EUT during operation. It verifies the EUT's potential to affect other equipment susceptible to electromagnetic emissions (i.e., aircraft navigation and communications equipment).

b. Conducted Emissions (CE-102), "Conducted Emissions, Power Leads, 10 kHz to 10 MHz.": For Air Force aircraft applications, conducted emissions were tested throughout the entire band of 10 kHz - 10 MHz. This test measured emissions generated by the EUT along its power supply lines. It was performed to assess the EUT's potential to affect other items connected to the same power source, particularly aircraft systems.

c. Radiated Susceptibility (RS-103), "Radiated Susceptibility, Electric Field, 10 kHz to 40 GHz.": For Air Force aircraft applications, radiated susceptibility was tested in a narrower frequency range from 30 MHz - 12.4 GHz at the following field strength levels: 20 V/M below 1 GHz and 60 V/M above 1 GHz (MIL-STD-461D field strength values from Table IV, Category Aircraft Internal). This test evaluated the EUT's resistance to predefined levels of EMI generated by antennas both internal and external to the aircraft.

d. Conducted Susceptibility (CS-101), "Conducted Susceptibility, Power Leads, 30 Hz to 50 kHz.": For Air Force aeromedical aircraft applications, conducted susceptibility was tested throughout the entire frequency band, from 30 Hz to 50 kHz. This test evaluated the EUT's ability to "withstand ripple voltages associated with allowable distortion of power source voltage wave forms."

e. Conducted Susceptibility (CS-114), "Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 400 MHz.": For Air Force aeromedical aircraft applications conducted susceptibility was tested throughout the frequency band from 10 kHz to 200 MHz. This test determined whether "simulated currents that will be developed on platform cabling from electromagnetic fields generated by antenna transmission would affect the equipment under test."

f. Conducted Susceptibility (CS-115), "Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation": This test was performed to ensure the EUT could withstand the "fast rise and fall time that may be present due to platform switching operations and external transient environments such as lightning and electromagnetic pulse."

g. Conducted Susceptibility (CS-116), "Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz - 100 MHz," respectively. The "basic concept of this test is to simulate electrical current and voltage waveforms occurring in platforms from excitation of natural resonances." During emissions testing, all EUT's electrical components were operating for the duration of the test to create the worst case emissions scenario. In these tests, the EUT was loaded down to draw maximum current and monitored for signal stability. For susceptibility testing, the EUT was loaded down again to draw maximum current and monitored for signal stability. For both emissions and susceptibility testing, the EUT was tested for operation on 115 VAC/400 Hz power.

THERMAL/HUMIDITY ENVIRONMENTAL CONDITIONS

Extreme temperature and humidity testing determines if aeromedical equipment can be stored and operated during severe environmental conditions without experiencing physical damage or deterioration in performance (6). Extreme environmental conditions can have incapacitating effects on medical equipment including the following; changes in material characteristics and material dimensions, overheating, changes in electronic components, and electronic or mechanical failures due to rapid water or frost formation.

Testing was conducted in the calibrated Thermotron Industries, model SM-32 environmental chamber. The EUT was placed in the center of the environmental chamber. All input and output cables and wires were routed through a port in the chamber wall, which was subsequently sealed with a precut sponge plug. The other components of the test setup remained outside the chamber. For operational tests, the EUT was monitored continuously, and a performance check was conducted every 15 minutes. For storage tests, the EUT was placed in the chamber and remained non-operational throughout the storage portion of the test. The following describes the conditions of the environmental tests performed:

a. Humidity: 94 ± 4% RH, 85°F ± 3.6°F (29.5°C ± 2°C) for 4 hr

b. Hot Temp Operation: 120°F ± 3.6°F (49°C ± 2°C) for 2 hr

c. Cold Temp Operation: 32°F ± 7.2°F (0°C ± 4°C) for 2 hr

d. Hot Temp Storage: 140°F ± 3.6°F (60°C ± 2°C) for 6 hr

e. Cold Temp Storage: -40°F ± 3.6°F (-40°C ± 2°C) for 6 hr

HYPOBARIC CONDITIONS

Cabin Pressure/Altitude: Altitude testing is critical for aeromedical evacuation equipment due to potential effects of barometric pressure changes on the equipment. A majority of the aircraft characterized as opportune aircraft available for use in aeromedical evacuation pressurize their cabin atmosphere to barometric pressures equivalent to 8,000 - 10,000 ft above sea level. The differences in pressures affect the operation of some medical equipment. Altitude testing consisted of operating the EUT while ascending from ground level to 10,000 ft; stopping at 2,000 ft increments for performance checks; and then descending back to ground again stopping at 2,000 ft increments for performance checks. The rates of ascent and descent were 5,000 ft/min.

Rapid Decompression Testing: A rapid decompression (RD) is the loss of aircraft cabin pressurization and subsequent pressure equalization with ambient atmospheric pressures. It is important to assess medical equipment functioning during and after RD so as not to endanger patients, personnel, or the aircraft. The EUT operated inside the rapid decompression test chamber as the chamber was pressurized to an equivalent of 8,000 ft altitude. Then the chamber altitude was brought to 45,000 ft over a period of 60 seconds, held at 45,000 ft for a few minutes, and then returned to ground at a rate of 10,000 - 12,000 ft/min. The test was repeated twice more; once for a 7 second RD and once for a 1 second RD. The EUT was monitored throughout the series of decompressions; performance checks were assessed each time the unit returned to ground level.

AIRBORNE PERFORMANCE

Airborne performance evaluations are a cost-effective and invaluable means of validating clinical and operational suitability under actual operating conditions. By carefully evaluating medical equipment items in there proposed operational environment. Inflight test and analysis demonstrates the EUT's ability to provide patient care onboard USAF aircraft. Safe and reliable operation is the primary goal of the inflight evaluation and forms the basis for subsequent recommendations to the users.

This phase of testing was conducted by qualified aeromedical crewmembers from the Air Force Medical Equipment and Development Laboratory on C-130 and C-141 aeromedical evacuation missions. The EUT was positioned and secured to the aircraft floor using USAF cargo tie-down straps and then evaluated. Human factor characteristics, securing methods, setup/tear down times and securing locations were also evaluated. Feedback from other aeromedical evacuation crew members participating in delivery of patient care was obtained concerning EUT human factor considerations.

EVALUATION RESULTS

INITIAL INSPECTION

Initial inspection revealed no manufacturing defects. The unit performed to the manufacturer's specification. Electrical safety test results showed all parameters to be within referenced guideline limits.

VIBRATION

The EUT in the "Z" axis random test experienced a loosening of one of the lug connectors that provides power to the middle receptacle. This loosening was due to the lack of lock washer placement when unit was assembled. The manufacturer was notified that procedures need to be incorporated into manufacturing the unit to prevent this from happening again. Once repairs were accomplished and guidelines established the EUT went back through "Z" axis random vibration without any system degradation. AFMEDL staff concluded that the unit passed vibration testing and can be used onboard all Air Force aeromedical evacuation aircraft.

ELECTROMAGNETIC COMPATIBILITY

ASC/ENAI, Wright-Patterson AFB certified the EUT for use in aeromedical evacuation system on all U.S.Air Force aircraft while operating from 115 VAC/400 Hz power.

THERMAL/HUMIDITY ENVIRONMENTAL CONDITIONS

The EUT operated satisfactorily during all five phases of testing.

HYPOBARIC CONDITIONS

1. Cabin Pressure/Altitude: The EUT performed in accordance with manufacturer's specifications throughout testing. Voltages and signal waveform across loads from each receptacle on EUT were monitored with no systems deficiency noted.

2. Rapid Decompression: The EUT operated satisfactorily following each rapid decompression event.

AIRBORNE PERFORMANCE

The inflight evaluation of the EUT was performed on C-130 and C-141 aeromedical evacuation missions. Evaluation confirmed that the unit would operate successfully during all phases of flight. Analysis of performance data indicated this unit was easy to enplane and deplane and was compatible with aircraft electrical systems. During evaluation it was noted that the unit did not have protective guards around circuit breaker switches to prevent accidental shut-off and possible switch damage. Placement on the aircraft; the EUT should be placed to enhance the crewmembers ability to view operational lights along unit side and also prevent obstruction of units cooling fans intake and output ports.

SUMMARY

AFMEDL found the Unitron, Inc. model Ps-95-448-1, Medi-Vac Portable Power System to be acceptable for use on all USAF aircraft (including small and large body, fixed and rotary wing) while operating on 115 VAC/400 Hz power with the recommendations listed below. Its operation was within expected parameters when subjected to electromagnetic interference (EMI); environmental extremes, simulated cabin altitudes, and did not produce a hazard to patient or crew during rapid decompression. Changes in structural components were necessitated due to component improvements based on vibration testing and human factor analysis. The following modifications were made:

a. Frame was strengthened following human factors and device securing evaluation onboard aircraft to prevent damage to outer casing during operational life. Reinforcement modifications include:
    1) Placing two tubular bars along the front and back (long sides) of unit.
    2) Welding reinforcement plates to the inside left and right sides (short sides, where handles mount) of unit.
    3) Hardening handle mounting bolts.

b. Two small holes in the lower outer equipment casing were occluded with rubber seals and ¾" tubular skids installed to prevent inadvertent entry of water into the unit.

c. Power receptacle switch guards made in contrasting colors were added to protect receptacle switches from inadvertent strikes and tip overs during handling.

d. Power switch retaining screws were shortened to 5/16" to prevent breakage of the plastic switch housing receptacles.

e. A label was added under receptacles to read "MAXIMUM LOAD: 15 AMPS PER OUTLET, 30 AMPS TOTAL"

REFERENCES

1. National Fire Protection Agency (NFPA) 99, Health Care Facilities Code

2. Emergency Care Research Institute (ECRI)

3. AFI 41-203, Electrical Shock Hazards

4. AFI 41-201, Equipment Management in Hospitals

5. MIL-STD 1472, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities.

6. MIL-STD 810E, Environmental Test Methods and Engineering Guidelines.

7. MIL-STD 461D, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference.

8. MIL-STD-462 D, Measurement of EMI Characteristics.

9. Unitron, Inc., Model Ps-95-448-1, Medi-Vac Portable Power System, Operations & Service Manual.

10. Aeromedical Research Procedures Guide, Internal Operating Instruction, Systems Research Branch, Armstrong Laboratory.

APPENDIX
MANUFACTURER'S SPECIFICATIONS OF UNITRON, INC., MODEL PS-95-448-1, MEDI-VAC PORTABLE POWER SYSTEM

SPECIFICATIONS

General

Size	12 .75in. H. x 10.5 in. W. x 23 in. D.
Weight	51.16 lbs.
Power	**Input**: voltage range-115/200 VRMS ±10%. 3-phase, wye, grounded neutral, frequency range-360 to 440Hz, protection-circuit breaker, over/under voltage, loss of phase, and over current. **Output**: 3.5 KVA continuous, overload-125% for 5 minutes, 175% for 10 seconds (10% duty cycle), configuration-single phase, voltage-115 VRMS ± 1.0%, frequency-60Hz ± 0.1%, efficiency-85% minimum at full load rating, protection-over/under voltage, overload and short circuit, duplex receptacles individually circuit breaker protected.
Cooling	Self-contained fan
Altitude	15,000 ft (operating) and 50,000 ft (storage)
Environmental	Temperature: -20°C to 55°C (operating). -40°C to 85°C (storage and shipping). Humidity: 95% RH at 30°C